WADC TECHNICAL REPORT 53-498

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TRANSFER OF TRAINING IN A SIMPLE MOTOR SKILL ALONG THE SPEED DIMENSION

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MARCH 1954

WRIGHT AIR DEVELOPMENT CENTER

AF-WP-(B)-O-10 JUN 54 125

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Aero Medical Laboratory
Contract No. AF 33(038)-10196
RDO No. 694-17

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report is based upon research which was conducted by the University of Louisville under USAF Contract No. AF 33(038)-10196. The contract constituted a sub-project under Research and Development Order 694-17, "Design and Arrangement of Aircraft Controls." The sub-project was 694-17C, "Factors Influencing Speed and Accuracy of Manual Movement." The contract was administrated by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center with Dr. W. C. Biel, Mr. M. J. Warrick and Mr. R. L. Morgan acting as Project Engineer during successive phases of the contract.

Included among those who cooperated in the study were Andrew J. Eckles, Jr., and R. Gene Farr, both of the Department of Psychology, University of Louisville, who aided in collection and analysis of the data. The girls who volunteered as subjects and the officials of their schools or other groups who participated in a variety of ways provided indispensable assistance. Special thanks are due Mr. W. F. Coslow, Supervisor of Secondary Education, of the Board of Education; Sr. Grace Marie of the Academy of Our Lady of Mercy; Mrs. Ralph P. Long, Executive Secretary, and Miss Dorothy O'Dell, Referral Secretary of the Volunteer Association of the Community Chest; Mr. M. Osbrink, Choir Director of the Walnut Street Baptist Church; Sr. Paracleta of the Holy Rosary Academy; Mr. A. J. Ries, Principal of DuPont Manual High School; Rev. A. W. Steinhauser of St. Aloysius Church; and Miss Emma J. Woerner, Principal of Atherton High School.

ABSTRACT

The required speed of response is one of the many dimensions along which tasks vary. Although it is well-known that, in general, as the speed of a task increases, proficiency of performance decreases, the relationship between the performance of a first and second task as a function of the difference in their speed requirements is not so well known. For optimal performance of a second task there must be some best speed of the first or training task. At present, however, the specification of the speed for the optimal training task (for any given second task) must be based upon speculation unsupported by reliable data. The study being reported was designed to obtain information on the general problem of the influence of the speed of a training task upon the performance of a following task.

The task used in the research was rotary pursuit at four different speeds. The speeds were assigned to the training and transfer periods in such a manner as to obtain all 16 possible combinations of speeds in the two periods. The 16 different combinations of speeds were presented under three different conditions of distribution of practice; thus, a total of 48 subgroups were employed in the experiment.

It was found that the greater the speed of the task, the poorer the performance. And, in general, when the rate of the final task was equal to or lower than the rates of the training tasks, transfer of training was directly proportional to the similarity between the rates of the two tasks. However, when the speed requirements of the final task were quite great, all training conditions produced about the same time-on-target scores; but, in terms of percent transfer scores, the best training speed was slower than the final speed. These findings were independent of the distribution of practice conditions.

The apparent inability of present transfer theories to account for these and other motor skills transfer phenomena is discussed. The limitations of current theories are attributed to the fact that they are based on research with tasks which do not vary in difficulty when inter-task similarity is manipulated by variations along a single task dimension.

The implications of these results for the design of training equipment are that the speeds of training tasks should not exceed those for corresponding operational tasks and sometimes (when operational speeds are high) they should be slower than the operational tasks for which training is intended. Added confidence in the generality of the findings of this experiment will be achieved by further research with other tasks and higher degrees of original learning.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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INTRODUCTION

When an organism learns to perform a particular task, then shifts to the learning of another task, there is usually a "transfer" effect. That is, learning the second task is easier or harder as a result of having learned the first task. Many kinds of things are transferred from one task to another in this way; specific response tendencies, work methods, principles, set, and stimulus differentiation are among the most important. An extensive discussion of what is tranferred can be found in books by McGeoch and Irion (15) and Underwood (19).

All human learning can be said to be doubly affected by transfer. If there is little transfer to the new task from tasks previously learned, it is probable that performance will start at a relatively low level and improve relatively slowly. The fact that the initial performance of almost all tasks becomes greater with increasing age during childhood, can be accounted for in this way as due to increasing amounts of transfer. The second effect comes within the task itself. Performance on trial 2 is affected by transfer from trial 1, performance on trial 3 is affected by transfer from trials 1 and 2, etc. In brief, the task is not the same perceptually to the learner from trial to trial, and learning what is objectively the "same" task from trial to trial can be considered as a transfer problem (cf. 19, p. 510). In any case, very general transfer within and between tasks is an accepted fact (8, 15, 16, 19).

Early speculators about transfer generally agreed that the more similar the tasks being studied, the greater the transfer from learning one to learning the other. A variant of this was the proposition that what is transferred could be considered identical elements (18, 15, pp. 342-343). Recent theorists (8, 16, 19) have based their formulations principally on findings in verbal learning, identifying, in general, three transfer conditions; transfer when only the stimulus is changed, transfer when only the response is changed, and transfer where both stimulus and response are changed. Underwood (20) predicts that there will be positive transfer along both the stimulus and response continua. He also states elsewhere (19) that reinforcement of the response during the learning of the first task results in some simultaneous strengthening of similar responses. Another theorist, Osgood (16), predicts that for the range from moderate similarity to identity, when stimulus and response vary together, the more similar they are to those in the original task, the greater the positive transfer. Unfortunately, the generality of these predictions is somewhat restricted because the research data upon which they are based represent only a limited segment of the total population of task conditions to which one might wish to apply the predictions.

Most investigations of the relationship between intertask similarity and transfer of training have utilized tasks which remain of uniform difficulty despite considerable variation along stimulus and/or response dimensions. For example, the similarity relationships among verbal stimuli and responses can be altered greatly without any associated variation in the difficulty of the experimental task.[1] Although to control one variable (difficulty) and manipu-

1. In this report all references to "similarity relationships" and "similarity" as a variable concern inter-task similarity--the similarity between two tasks.

late another (similarity) is scientifically sound, it sometimes produces task conditions which resemble only a restricted range of those which exist elsewhere. Frequently, both in real life and in the laboratory, variation along one dimension changes both intertask similarity and task difficulty. For example, as similarity is manipulated by changes which alter the perceptual-motor skill, e.g., control-display ratio (6, 10), temporal delay between control and display action (13), complexity of response pattern (13, 17), task speed (11), etc., task difficulty also is altered. Even in verbal tasks, it is possible to alter intertask similarity by variations along dimensions such as familiarity or meaningfulness, which also influence the difficulty of the task. Since most investigations have used task conditions quite unlike those which frequently exist, the generality of currently available experimental data, as well as theories based on those data, is open to question.

The results of several studies (6, 10, 12, 13, 17) indicate some exceptions to the commonly accepted relationship between intertask similarity and transfer of training. These investigations have demonstrated that the magnitude of transfer between two tasks of unequal difficulty may vary greatly depending on the order in which they are learned, even though the similarity relationships between the two are influenced very slightly, if at all, by their relative sequence. In certain circumstances (6, 10, 12, 17) the influence of an easy task upon a difficult one appears to be less than the effect of the same difficult task on the easy one. However, the reverse is true in other cases (13). Since these studies only indicate the existence of some exceptions to the general rule and leave unknown the necessary and sufficient conditions for these exceptions, additional research will be required in order to understand more completely both the limitations of the general principle and the nature of the exceptions to it.

The present research represents an attempt to investigate systematically the relationship between intertask similarity and transfer of training in a situation where variations in similarity are achieved by changes along a dimension which influences task difficulty. The purpose of the study was to contribute to a more adequate comprehension of the phenomenon of transfer of training and also to answer the practical question of what is the optimal speed of the training task for any one of several speeds of a second task.

METHOD

Subjects:

A total of 193 girls served as subjects (Ss). One record was discarded because of apparatus breakdown and failure to record performance. The girls were all from grades 10, 11, and 12, ranging in age from fifteen to nineteen years. All were volunteers, naive to the task, and practiced only during school hours. This age and sex group was run because it was readily available, and because Ammons, Alprin, and Ammons (1) had found that the characteristics of their performance are the same as those of boys and young men.

Apparatus:

A 4-turntable rotary pursuit device was used. Each turntable was 11 inches in diameter with a round brass target 3/4 inches in diameter set flush with its surface. The center of the target was 3 1/4 inches from the center of the turntable. Eight .001-minute 6V. Standard Electric timers recorded

scores, banks of four being used alternately. The clocks started and stopped at the same time as the turntables. The styli were hinged at the handle with a 6-inch section free-swinging. Their silver tips rested with a weight of approximately 0.6 ounces on the turntables. The construction of the stylus has been described in detail elsewhere (3). Variable-speed Green Flyer motors were used to revolve the turntables. They had been calibrated so that their rate of rotation could be set quickly by a lever. This setting gave a speed varying from the standard by two rpm at most in individual instances, and by only a very samll fraction of an rpm on the average.

Experimental Design:

Since it had been decided to study transfer along a continuum of rate of rotation (speed) of target, it was necessary to choose a set of speeds at which to have Ss practice. Helmick (11) had found that 50, 60, and 70 rpm were satisfactory rates. We tested 40 rpm and found that learning was sufficiently slow to be studied. The final rates decided on were 40, 50, 60, and 70 rpm. A different group of 48 Ss practiced for 5 minutes during Period 1 at each of the four speeds. Then, during Period 2, one quarter of each group switched to each of the four speeds and practiced 8 minutes. The basic design is shown in Table I. Thus, there were 16 conditions in the basic factorial design,

TABLE I

Basic Experimental Design Showing the 16 Conditions

Practice Speed during Period 1 (rpm)	Practice Speed during Period 2 (rpm): 40	50	60	70
40	40 - 40	40 - 50	40 - 60	40 - 70
50	50 - 40	50 - 50	50 - 60	50 - 70
60	60 - 40	60 - 50	60 - 60	60 - 70
70	70 - 40	70 - 50	70 - 60	70 - 70

providing all possible combinations of the four speeds in Period 1 with the four speeds in Period 2. Twelve Ss were in each of the 16 conditions.

In order to assess the effects of temporal distribution of practice on the transfer process, three very different conditions of distribution were chosen:

(a) 5-min. continuous practice, 30-sec. rest (to change rotor speeds), 8-min. continuous practice.

(b) 5-min. continuous practice, 5-min. rest, 8-min. continuous practice.

(c) 1-min. practice, 2-min. rest all through both practice periods.

These distributions were used because continuous practice is the most highly massed practice possible and previous work (4) had shown that practice periods separated by 2-min rests give optimum performance. The 5-min rest was introduced to allow a complete recovery from the temporary decremental effects of the continuous practice (2) in Period 1 before starting practice in Period 2. The 16 basic conditions shown in Table I were subdivided for each of the three conditions of distribution. Thus, there was a 4x4x3 factorial design (48 conditions).

Procedure:

The Ss came to the testing rooms in groups of four. They were randomly assigned as a group to one of the 48 conditions. It was explained that this was an Air Force test used for selecting pilots and that they should try to do well by relaxing and trying to keep on the target with an easy swinging movement of the arm. A tennis type grip on the stylus was demonstrated, and Ss' grips were checked. Questions were answered by rephrasing the instructions. During rest periods Ss sat down and relaxed or talked quietly.

RESULTS AND DISCUSSION

After several transformations of data had been tried, it was found that with a square root transformation Bartlett's test (7) showed the null hypothesis with regard to homogeneity of variance to be tenable at all points where analysis of variance was contemplated. That is, the hypothesis that the variances of scores in the 48 groups varied only by chance could not be rejected. The actual figures are given in Table II.[1]

TABLE II. RESULTS OF ANALYSES OF VARIANCE AND BARTLETT TEST OF HOMOGENEITY OF VARIANCE AT VARIOUS POINTS IN PRACTICE, USING SQUARE ROOT TRANSFORMATION O. RAW SCORES

Source of variance estimate	Degrees of Freedom	Variance estimates at various points in practice				
		First minute first period	Last 2 minutes first period	First minute second period	Second minute second period	Last 2 minutes second period
(A) Speed in first period	3	1003.2 **	2431.3 **	128.7 **	40.7	34.9
(B) Speed in second period	3	15.0	48.3	712.0 **	879.7 **	1751.5 **
(C) Rest condition	2	12.7	2054.3 **	446.6 **	721.7 **	2346.8 **
A x B	9	7.0	34.4	74.6 **	75.2 **	25.4
A x C	6	12.4	47.3	18.3	22.7	26.0
B x C	6	14.6	21.4	17.5	15.7	25.9
A x B x C	18	19.2 *	47.7 *	23.2	11.1	38.7
Within groups	144	10.0	26.5	17.8	20.8	30.8
Bartlett test+ of homogeneity of variance based on chi-squares	47	52.29+	58.01	56.43	33.73	64.07

** Significant at 1 percent level of confidence against within groups error term.

* Significant at 5 percent level of confidence against within groups error term.

+ Figures given in row are chi-square, which, with 47 degrees of freedom, must be 67.28 and 74.65 to be significant at the 5 and 1 percent levels of confidence, respectively.

1. The appendix contains a summary table of means for all 48 groups at all of the points in practice where analyses of variance were computed.

Variance of the scores was then analyzed for Minute 1 of Period 1, the last two minutes of Period 1, Minute 1 of Period 2, Minute 2 of Period 2, and the last two minutes of Period 2. The results of these analyses are also presented in Table II. It will be noted that the AxBxC interaction is significant at the five percent level of confidence during Period 1. This may have arisen from the use of intact groups; although the use of small intact groups in a previous study (4) did not result in a significant second-order interaction. Fortunately, the significance of the statistical tests during Period 1 are unaltered when the AxBxC interaction, rather than the within groups variance estimate, is used as the error term. The AxBxC interaction is not significant during Period 2.

Effects of Temporal Distrubution of Practice:

The analyses of variance in Table II indicate that distribution of practice has little or no effect during the first minute of Period 1, before there actually has been any differential treatment of the groups. At all points thereafter it has a highly significant effect. Figure 1 gives the mean

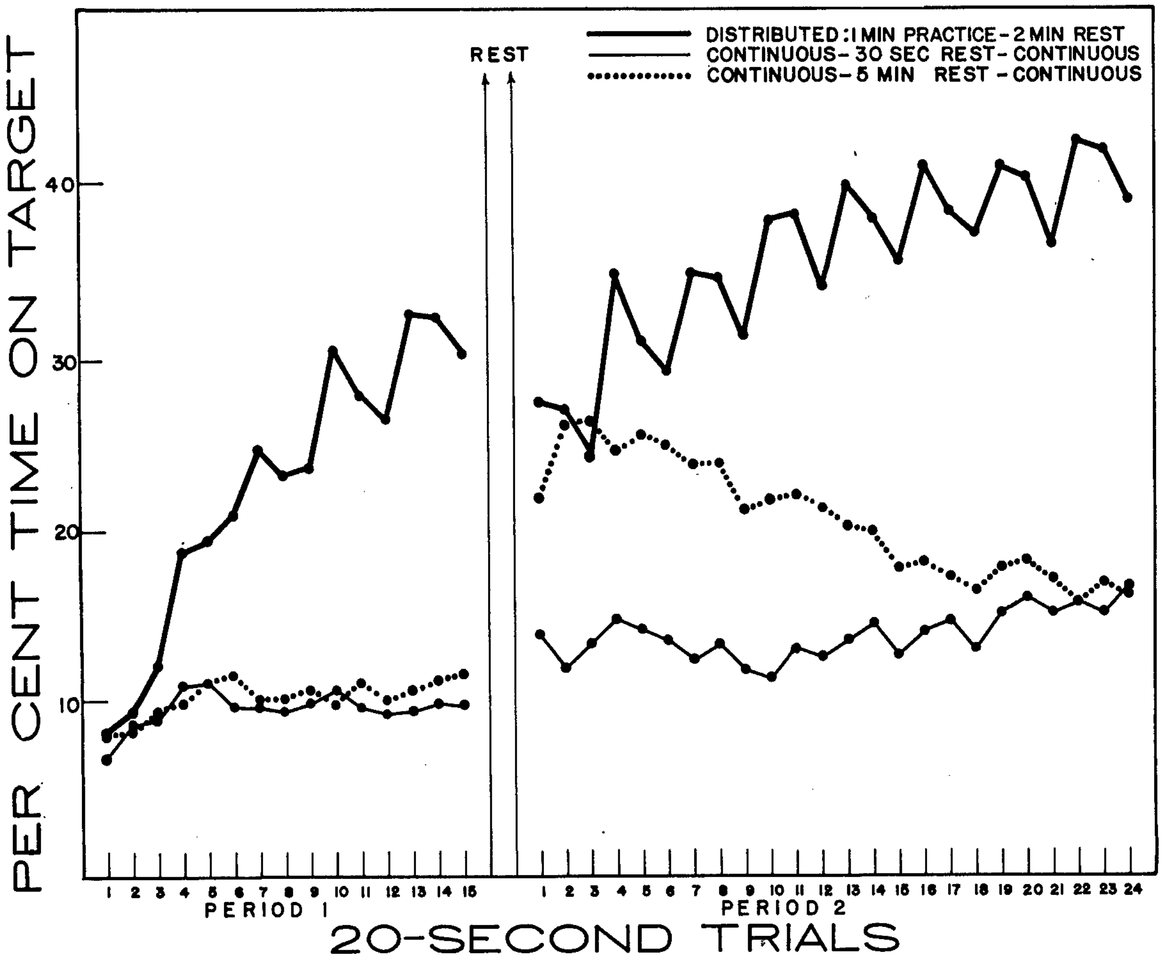

Figure 1. Mean performance of the groups practicing with the three distributions of practice. N = 64 at each point.

performance curves when all groups are combined into the three distribution groups. The continuous practice groups perform about the same during Period 1. The one shows a little reminiscence or gain over the 30-sec rest, while the other shows a large gain over the 5-min rest. This 5-min rest group shows changes during Period 2 which are typical (2) of continuous practice groups after a rest several minutes in duration; warm-up decrement, then a high point, then a decline to the level of the group with little or no rest. The group with 1-min practice sessions separated by 2-min rests remains at a high level during both periods. The performance of this group displays an interesting, fairly regular, "sawtooth" effect, being high during the first 20-sec trial of a 1-min period, then dropping progressively lower on the next two 20-sec trials. This effect probably is due to the accumulation of work decrement during continuous practice.

Since the 1-min practice, 2-min rest group curve and the curve for the continuous-practice group with a 5-min rest are at essentially the same level at the start of Period 2, this suggests an equal amount of transfer by these two groups, and perhaps also an equal amount of learning in Period 1, although the performance levels are very different. The performance of the 5-min rest group falls gradually to the level of the 30-sec rest group, indicating that the 5-min rest has produced no permanent effect although it has produced a large temporary effect at the start of Period 2. These findings of no permanent distribution effects are in agreement with findings in previous rotary pursuit studies (4; 5).

An examination of Table II reveals that there is no statistically significant interaction between degree of distribution and target rate at any point in practice. This means that the distribution conditions maintain the same position relative to each other, regardless of target rate. Although the absolute level of all three distribution conditions varies greatly from one target rate to another, the magnitude of the differences among the three conditions does not vary significantly. (For example, although the absolute magnitude of the set of numbers 5, 10, and 18 differs from the magnitudes represented by 105, 110, and 118, the differences among the three numbers in one set are the same as the differences among the numbers in the other set.) Since the differences among the distribution conditions probably are caused by different amounts of work decrement, the differences among the amounts of work decrement for the various conditions presumedly is also uninfluenced by target rate. If one assumes that for all the target rates, the condition of greatest distribution produced little or no work decrement (or that any one distribution condition produced the same amount of work decrement at each of the several target speeds), then the results of this experiment lend some support to Helmick's finding (11) that reminiscence is nearly equal for 60, 70 and 80 rpm groups. The information offered by the two studies is not exactly comparable, since reminiscence presumably is proportional to the absolute amount of dissipated work decrement, and the present results concern only the relative difference in amount of work decrement. Additional information concerning reminiscence at various target speeds can be obtained from Figs. 4, 5, 6 and 7.

The insignificant interaction also means that, although the absolute magnitude of scores for the various speed conditions varies from one distribution condition to another, the relative positions of the speed conditions is unaltered by different distribution conditions. This fact allows one to combine the data from the different distribution groups in order to assess the overall effects of target rate. Fortunately, since the second order

interaction was not significant during Period 2, the combined data may be used to examine the influence of changes in target rate on performance, i.e., the combined data may be used to analyze the significant interaction between Period 1 and Period 2 rates. The insignificant second order interaction indicates that the nature of the first order interaction between Period 1 rate and Period 2 rate remains the same for all degrees of distribution.

Effects of target rate:

Figure 2 gives the performance levels during Period 1 for the groups practicing with different target rates. It can be seen that the slower the rate, the better the performance, and that the differences are very large. The analyses of variance (Table II) indicate that this difference is statistically significant at a high level of confidence all through practice.

Transfer effects:

Figure 3 gives mean performance curves during Period 2 for Ss who practiced at the various target rates during Period 1. Thus, the curve for 40 rpm includes the scores during Period 2 of all Ss who had practiced at 40 rpm during Period 1. Since one-quarter were now practicing at 40, at 50, at 60, and at 70 rpm during Period 2, it can be seen that the four groups in Fig. 3 were equated with respect to current (Period 2) practice rate. Thus, any difference among them is due to differential transfer effects from Period 1.

Inspection of Fig. 3 reveals that there were markedly different amounts of transfer at the start of Period 2, and that the effects gradually disappear as practice continues. The over-all transfer effect is statistically significant during the first minute of Period 2, but not during the second minute or the last two minutes (Table II). The rapid dissipation of transfer effects is not an uncommon finding; however, the rate of dissipation in this experiment is somewhat more rapid than usual. The over-all transfer effects indicate that there was more transfer the slower the training speed. However, due to a statistically significant interaction between Period 1 and Period 2 rates, this general conclusion is limited to situations where the training and transfer tasks include all 16 combinations of the four rates. The significant interaction implies that some of the combinations do not adhere to this over-all rule. The nature and extent of the deviation from the general conclusion can be determined only by a comparison among the transfer effects of the 16 different conditions. The necessary comparisons can be made by an examination of the data represented in Figs. 4, 5, 6, and 7. These figures show the performance during Period 2 for Ss transferring from each of the Period 1 rates to a given rate in Period 2.

Figure 4 represents the performance of the four groups who transferred from various rates during Period 1 to the 40 rpm rate during Period 2. At least initially during Period 2, the groups differ considerably. The group which had experienced 40 rpm during Period 1 (40-40 rpm group) is markedly superior not only to the other three groups but also to its own performance level immediately before the change in rate. Although the rise in performance from Period 1 to Period 2 is apparent in each of the other figures, it is much more marked (33% to 55% time on target) for the 40-40 rpm group than for the other similar conditions. The rise between Periods probably is attributable to the dissipation (during the time between Periods) of inhibitory or decremental factors which developed during Period 1. When 40 rpm was the Period 2 rate, 40 rpm apparently was the best training rate and 70 rpm was

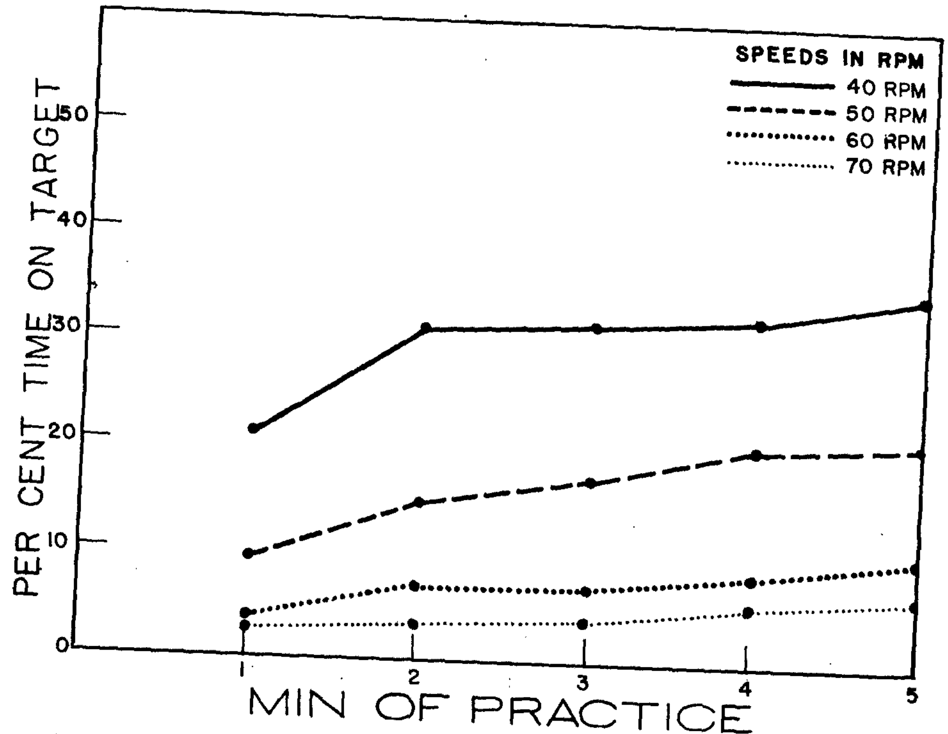

Figure 2. Performance as a function of target rate during Period 1. N = 48 at each point.

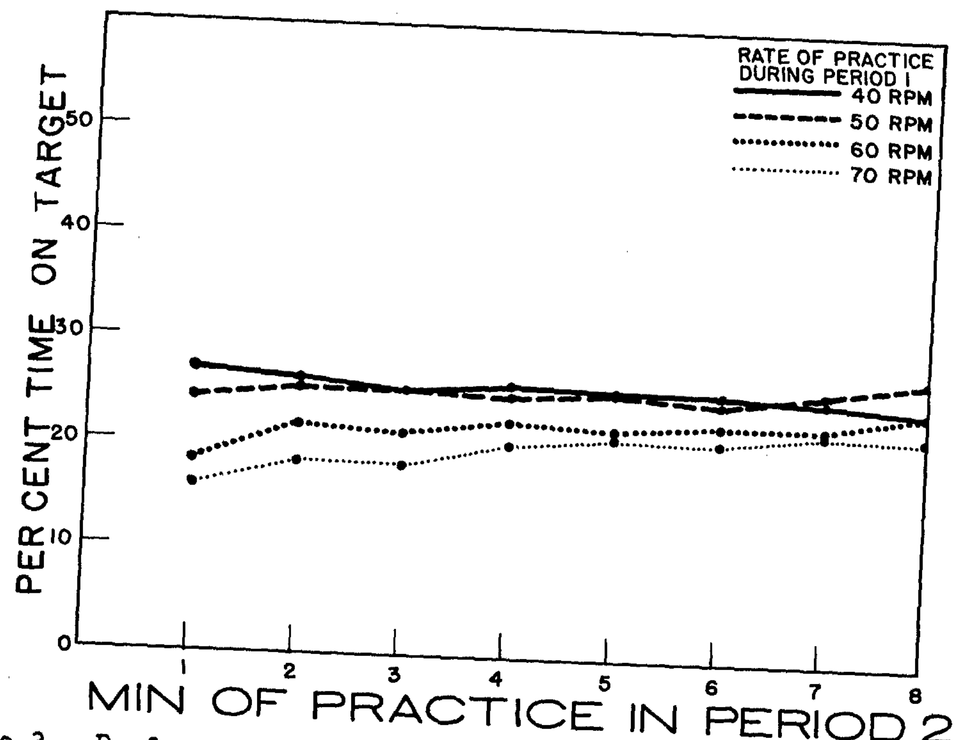

Figure 3. Performance during Period 2 of Ss who had practiced at each target rate in Period 1. $\bar{N}$ = 48 at each point.

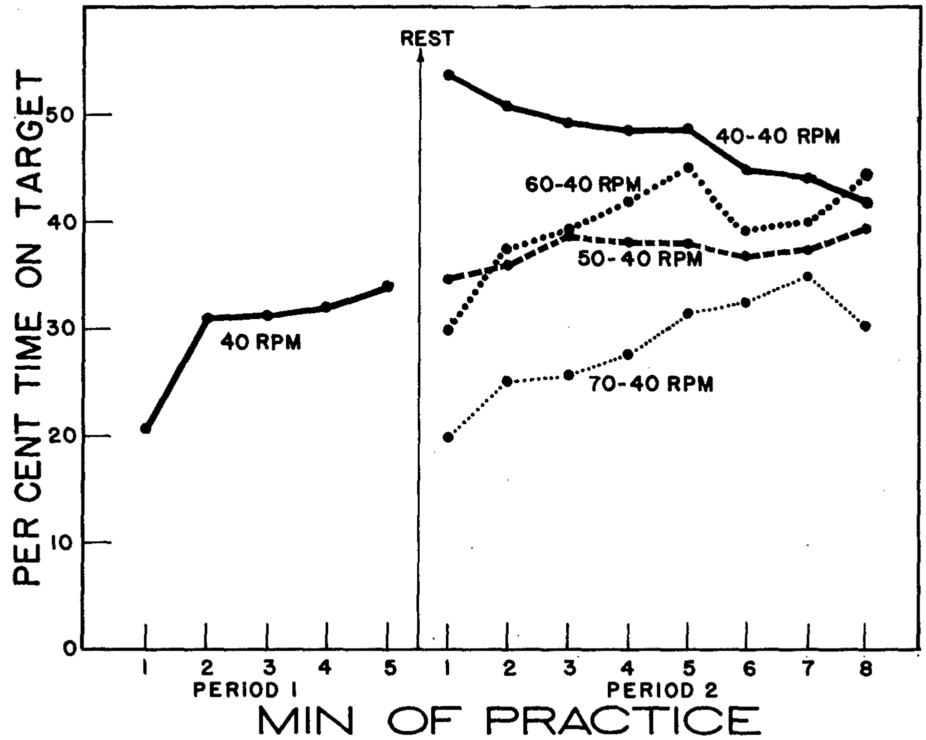

Figure 4. Performance during Period 2 of Ss who transferred from each of the Period 1 rates to 40 rpm in Period 2. N = 48 at each point in Period 1 and N = 12 at each point in Period 2.

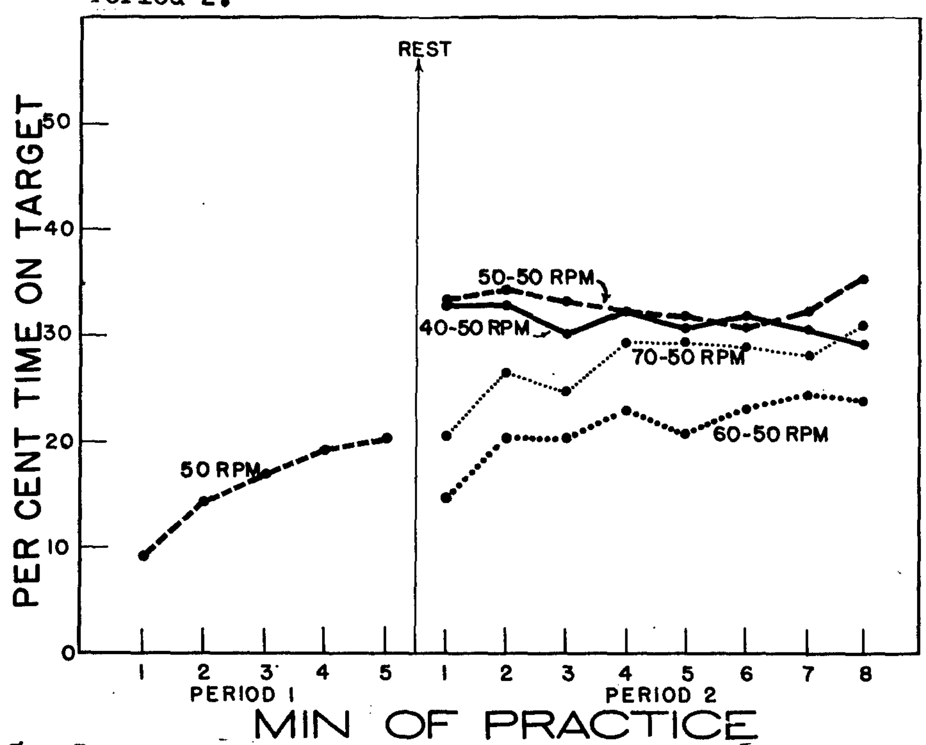

Figure 5. Performance during Period 2 of Ss who transferred from each of the Period 1 rates to 50 rpm in Period 2. N = 48 at each point in Period 1 and N = 12 at each point in Period 2.

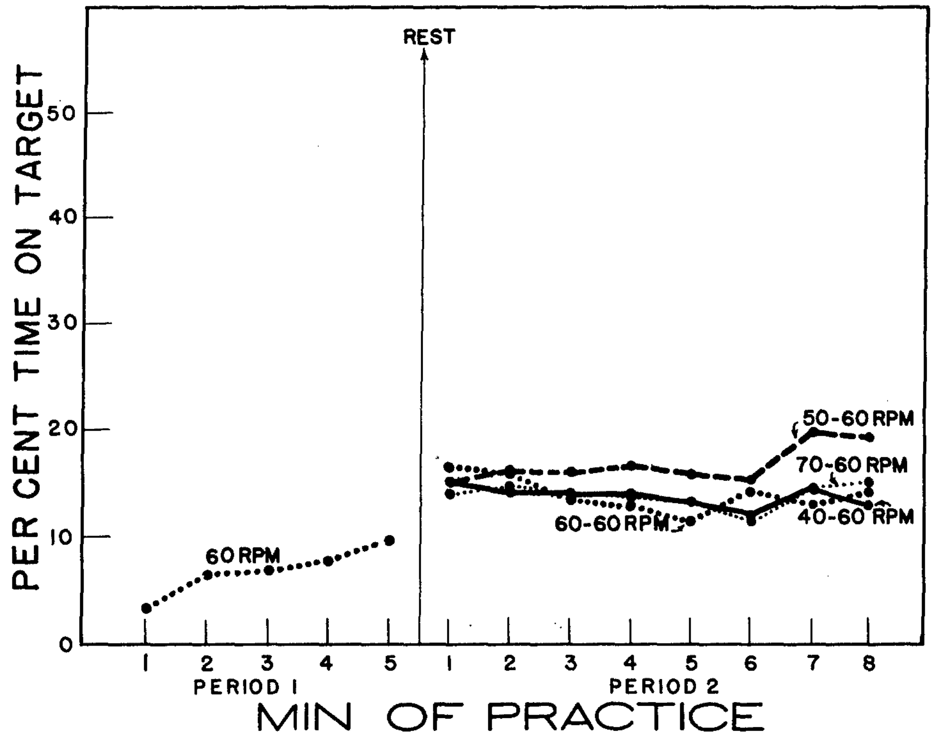

Figure 6. Performance during Period 2 of Ss who transferred from each of the Period 1 rates to 60 rpm in Period 2. N = 48 at each point in Period 1, and N = 12 at each point in Period 2.

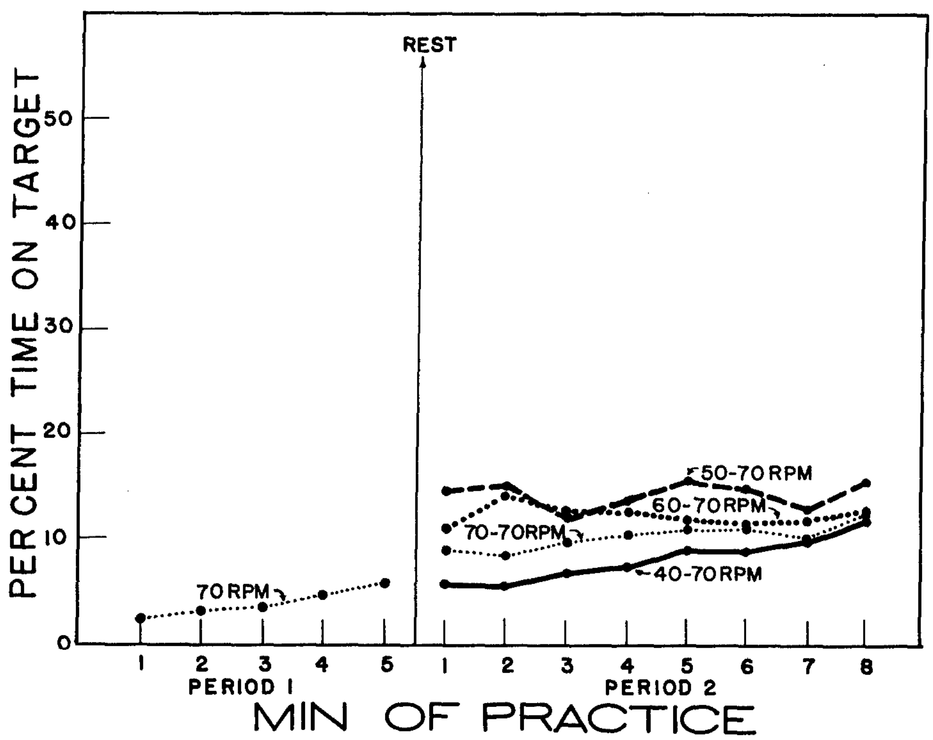

Figure 7. Performance during Period 2 of Ss who transferred from each of the Period 1 rates to 70 rpm in Period 2. N = 48 at each point in Period 1, and N = 12 at each point in Period 2.

clearly the poorest. The other two training speeds fall close together between these two extremes..

When 50 rpm was the Period 2 rate (Fig. 5) the differences between the groups are considerably smaller. Training at 40 rpm is almost as effective as training at 50 rpm, but the two faster speeds seem to produce considerably less transfer, with the 60-50 rpm group as the poorest of all. Not only do the relationships observed in Fig. 5 differ from those noted in Fig. 4, but they seem less regular.

As shown in Fig. 6, the differences between the groups are very slight and apparently without order when 60 rpm is the speed during Period 2. It would be almost impossible to defend one speed during Period 1 as the best training speed for the 60 rpm condition.

Although still quite small, the differences among the conditions represented in Fig. 7 are somewhat greater than the differences in Fig. 6. Both the 60-70 rpm and 50-70 rpm groups are superior to the 70-70 rpm groups but the 40-70 rpm group is poorest of all.

In terms of percent time on target (Figs. 4-7), the various rates during Period 1 have strikingly dissimilar effects on Period 2 performance only when the rate during Period 2 is quite slow (40 or 50 rpm). When the Period 2 rates are higher, the differences among the training conditions are slight. Apparently, when the speed requirements of the task are low, training at faster rates is less efficient than training at the slow speed. And, in general, the greater the difference in speeds, the less the transfer. However, when the speed requirements are quite high, all training speeds seem to obtain about the same percent time on target scores. It should be noted that these conclusions are restricted specifically to percent time on target scores which, while often of major practical importance, frequently do not have a one-to-one correspondence with other units of skill. For example, at 40 rpm an increase in time on target from 20 percent to 25 percent may represent a relatively small increase in skill (an amount acquired in less than 1 minute of practice) while an increase of comparable magnitude at 60 rpm may represent a much larger increment of skill (more than 5 minutes of practice). Likewise, at 40 rpm an increase from 20 to 30 percent time on target (1 minute of practice) undoubtedly represents a much smaller change in skill than the gain from 30 to 40 or 40 to 50 percent time on target. Although an examination of Figs. 4, 5, 6 and 7 has revealed the nature of the statistically significant interaction, an attempt will be made to measure the transfer of training which occurred in units which correspond more closely to degrees of performance proficiency than do percent time on target scores.

In the mathematical calculation of transfer from Period 1 to Period 2, Formula 3 from an article by Gagne, Foster, and Crowley (9) was used in a slightly modified form. The scores obtained by this formula represent the percent of improvement in performance of the control group (same Period 1 and Period 2 speed) that is accomplished by a transfer group (Period 2 speed same as for control group but Period 1 speed different). Improvement is measured from the first 2 minutes of Period 1 to the first or the last 2 minutes of Period 2. The formula is as follows:

$$\text{Transfer} = \frac{T_X - C_I}{C_X - C_I} \times 100$$

where T_X = score of "transfer" group (N = 12) during trial(s) X; in the present study, the first or last two minutes of Period 2.

C_X = score of "control" group (N = 12) during trial(s); in the present study, the first or last two minutes of Period 2.

C_I = score of "control" group during trial(s) I; in this study, the first two minutes of Period 1, for all Ss practicing at that speed. (See Fig. 2)

TABLE III. PERCENT TRANSFER SCORES FOR THE FIRST TWO MINUTES OF PRACTICE IN PERIOD 2

		Rate during Period 2				
		40	50	60	70	Row Mean
Rate during Period 1	40	(100)	96	88	53	79
	50	34	(100)	96	204	111
	60	28	25	(100)	164	72
	70	-13	53	85	(100)	42
	Column Mean	16	58	89	140	

TABLE IV. PERCENT TRANSFER SCORES FOR THE LAST TWO MINUTES OF PRACTICE IN PERIOD 2

Rate during Period 1	Rate during Period 2: 40	50	60	70	Row Mean
40	(100)	81	103	96	93
50	74	(100)	167	136	125
60	96	57	(100)	112	88
70	39	80	118	(100)	79
Column Mean	70	72	129	114	

Tables III and IV give the percent transfer scores for the first and last two minutes of Period 2. Although both tables indicate the same trends, in Table III they are much more pronounced than in Table IV. This fact is consistent, of course, with the fact that the analyses of variance of the time-on-target scores revealed statistically significant interactions only during the first two minutes of Period 2. When 40 rpm was the target speed during Period 2, the percent transfer scores indicate essentially the same relationships that were observed in Fig. 4. For this condition the 40 rpm training speed is far superior to all others, --- showing three times as much transfer as its nearest rival. For only the 70 rpm condition is there much difference between the conclusions based on percent time on target scores (Fig. 7) and those to be drawn from the transfer scores of Table III. Of course, both Fig. 7 and Table III represent the same general relationship, but in Table III it becomes apparent that the fairly small differences (5 to 6 percent) in time on target scores shown in Fig. 7 represent quite large differences in terms of percent transfer scores (100 vs 200 percent transfer). Training speeds of 50 and 60 rpm produced between one and a half to two times as much transfer as the 70 rpm training speed. At least in terms of percent transfer scores, when the speed requirements of a task are quite great, training with somewhat slower speeds seems to be more effective than training at the same fast speed. This conclusion should be accompanied with a note of caution, however, since no statistical tests were utilized to evaluate the statistical significance of differences among the percent transfer scores for the various groups.

A somewhat different picture of the overall transfer effects which were presented in Fig. 3 can be seen in Figs. 8 and 9. Figures 8 and 9, unlike Fig. 3, are based upon percent transfer scores. These scores were combined

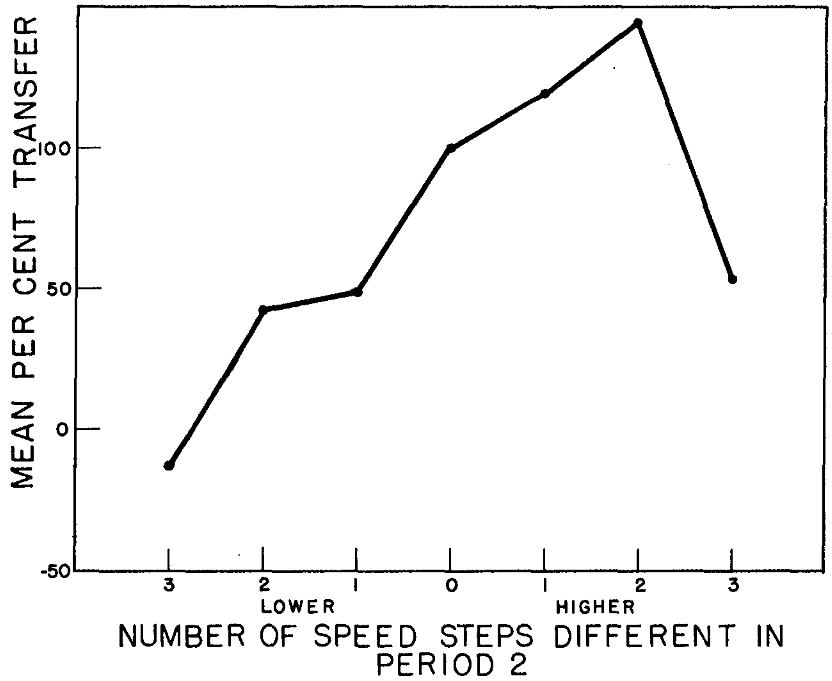

Figure 8. Mean per cent transfer during first two minutes of Period 2. Units on the abscissa represent changes in target speed from Period 1 to Period 2.

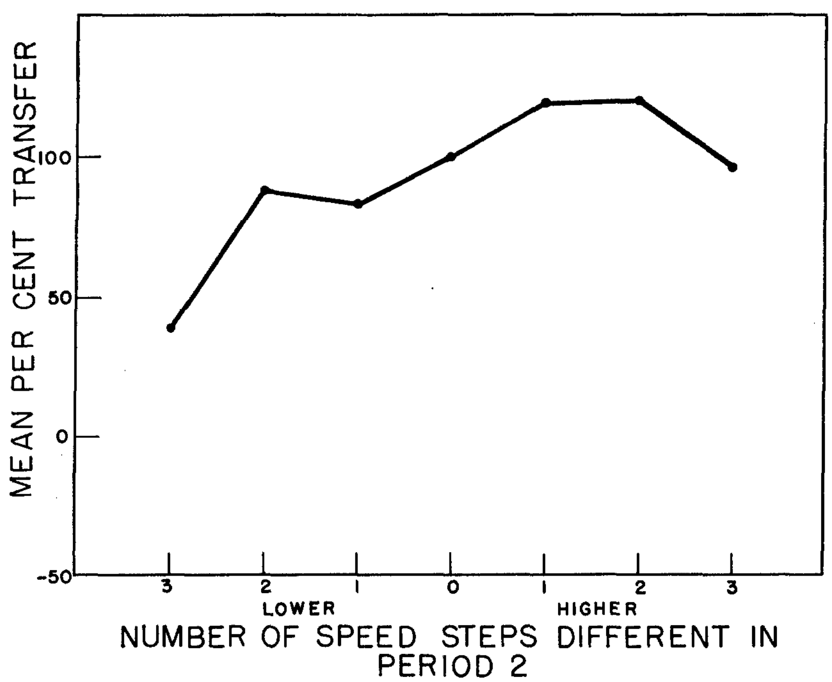

Figure 9. Mean per cent transfer measured during last two minutes of Period 2. Units on the abscissa represent changes in target speed from Period 1 to Period 2.

and then averaged by the amount and direction of stepwise change in rate from Period 1 to Period 2. A change from 40 to 50 rpm would be one step up; a change from 70 to 40, a change of three steps down. It will be seen that initial and final rates are not equally represented in all the steps, and that the steps involve different numbers of Ss. The number of subjects and the groups used at each point are given in Table V.

TABLE V. GROUPS USED IN CALCULATING THE DATA PRESENTED IN FIGURES 8 AND 9

Steps	N	Groups Included
Down 3	12	70 - 40
Down 2	24	70 - 50, 60 - 40
Down 1	36	70 - 60, 60 - 50, 50 - 40
No Change	48	70 - 70, 60 - 60, 50 - 50, 40 - 40
Up 1	36	40 - 50, 50 - 60, 60 - 70
Up 2	24	40 - 60, 50 - 70
Up 3	12	40 - 70

From Fig. 8 it is apparent that, in general, when the Period 2 rate is lower than the Period 1 rate, the transfer is less than 100 percent; and, the greater the difference between the two rates the less the transfer. However, when the Period 2 rate is higher than the Period 1 rate, two conditions produce more than 100 percent transfer and only when the Period 2 rate is three steps higher than the Period 1 rate is less than 100% transfer obtained. To a lesser extent the same trends appear in Fig. 9. Although conclusions based on these figures are restricted to the combinations of rates which are represented, they do lend support to the proposition that transfer of training between two tasks of unequal difficulty sometimes can and sometimes cannot be accounted for solely in terms of the similarity between the two tasks.

According to the results of this study, when the second task is a relatively easy one, and the training task is more difficult, transfer adheres to its usual relationship with similarity --- the greater the similarity the greater the transfer. A similar experiment by Levine (13), varying temporal delay between control action and display response instead of target rate, produced very similar results. None of the other studies which were mentioned

earlier contain evidence which is related directly to this finding. These latter studies found considerably more transfer from difficult tasks to easy ones than vice versa, however, according to the results of Levine's study and the present one, they might have found still more transfer using first tasks of lesser difficulty (and hence of greater similarity to the easy task). Although the evidence is scanty, the best available hypothesis seems to be that transfer of training and similarity are related directly when the second task is a relatively easy one and the training tasks are more difficult.

In the reverse situation, however, when the training tasks are easier than the second task, predictions based on similarity relationships are unconfirmed. In both the present study and one of Levine's experiments (13), when the second task was a difficult one, training tasks other than those of highest similarity produced the most transfer. However, in neither experiment was transfer inversely related to the similarity between tasks --- one could not conclude that the easier the first task the more the transfer to the second. Instead, it appeared as if both of these factors (ease of training task and similarity to the second task) were influencing transfer. These two conflicting factors offer a convenient explanation of both the present results and those of Levine; however, they are not adequate to explain the results of the several studies (6, 10, 12, 17) which have found greater transfer from difficult tasks to easy ones than vice versa. Apparently, all exceptions to the general relationship between transfer of training and similarity cannot be explained by the use of any simple combination of the effects of similarity and the degree of difficulty of the training task.

Before concluding, we would like to remark on a difficulty inherent in experiments involving different rates, such as the present one. During a given time period, an S practicing with the target moving at a greater rate is given more practice (the target revolves more times) than is an S practicing at a lesser rate. Opportunity could be equalized by allowing each S to practice during the same number of revolutions by the target, but this would introduce a new difficulty. The effects of rate on any variable associated with time spent practicing, such as temporary work decrement (2), could not be studied, since Ss would spend different durations of time practicing. If one were to try to bring all Ss to the same level of proficiency, this would call for much longer times in the situation for Ss practicing initially at the greater rates, and would also make study of time-associated variables impossible. There is thus no way to separate the time, proficiency, and rate variables. In this case, one must simply make an arbitrary choice of experimental design with a particular variable in mind. No one of the above designs is inherently more adequate than any other; it simply gives a different sort of information.

CONCLUSION

Transfer of training between tasks of different speed requirements was systematically investigated in a factorial experiment. The task was rotary pursuit and the two factors were target speed during the first (training) task and target speed during the second (transfer) task. A summary of the experimental findings is presented below.

(1) At all stages of practice, time on target scores were related inversely to the speed of the target.

(2) The relative rankings among three conditions of distribution of practice were not significantly influenced by the rate of the target during either task or the combinations of target rates in the two tasks.

(3) In terms of time on target scores, training tasks at speeds greater than the speed of the final task are less efficient than a training task at the same speed as the final task. And, the greater the difference in speed the less the transfer. On the other hand, training speeds somewhat slower than the speed of the second task are as effective as a training speed the same as the speed of the final task. Training speeds considerably slower than the final speed are not, however, as effective as the final task speed.

(4) In terms of percent transfer scores (which are roughly comparable for different task conditions), the same general relationships hold with but one exception: when the rate of the final task is quite rapid, somewhat slower rates produce up to twice as much transfer as the training task with the same rate as the final task.

The general implications of these results for the design of training equipment are that the speeds of training tasks should not exceed those for the corresponding operational tasks for which training is intended --- especially if the speed of the operational task places a considerable demand upon the ability of the operator.

It should be pointed out that the generality of this conclusion is somewhat restricted, since one fact which the present study has demonstrated is that transfer principles which are derived from one set of task conditions sometimes are not adequate to predict the results with other task conditions. In order to extend the generality of the present findings, two factors are especially worthy of investigation. These factors are (a) the type of task involved in training and transfer and (b) the degree of learning of the training task. Although the task which was used in the present experiment may represent many other simple perceptual-motor tasks, the amount of practice which was allowed is quite atypical of the amounts of practice which frequently are associated with human motor skills, especially in the military situation. And, as Miller (14) has suggested, there are many reasons to expect different transfer relationships with different degrees of learning. For example, in the present study, the findings that all training speeds produced about the same time-on-target scores when the final rate was very rapid might not have been obtained if Period 1 practice has extended for five hours or even 50 minutes instead of five minutes.

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APPENDIX

The scores in the following table represent the mean performance for each of the 48 subgroups at all of the points in practice where analyses of variance were computed. Each score represents the mean time on target (in thousandths of a minute) during 20-second trials. Percent time on target scores can be obtained by multiplying the scores in the table by .3.

The various subgroups are described by three numbers. The first and last numbers represent the target speed during Period 1 and Period 2, respectively. The numbers in the middle represent the three distribution of practice conditions. The continuous practice group is indicated by zero. Five represents the group which had 5 minutes of rest between Period 1 and Period 2. The group which rested 2 minutes after each minute of practice is indicated by the number two.

Subgroups	First Minute Period 1	Last 2 minutes Period 1	First Minute Period 2	Second Minute Period 2	Last 2 minutes Period 2
40 - 0 - 40	51	60	103	97	91
40 - 5 - 40	78	98	223	216	121
40 - 2 - 40	72	173	208	205	215
40 - 0 - 50	62	69	84	90	79
40 - 5 - 50	69	75	116	105	68
40 - 2 - 50	98	194	132	136	151
40 - 0 - 60	88	90	27	20	27
40 - 5 - 60	56	82	80	64	28
40 - 2 - 60	60	149	54	71	84
40 - 0 - 70	53	67	8	6	11
40 - 5 - 70	46	58	27	17	8
40 - 2 - 70	104	205	23	36	91
50 - 0 - 40	34	29	82	56	101
50 - 5 - 40	17	22	152	156	107
50 - 2 - 40	9	68	118	148	181
50 - 0 - 50	14	25	44	36	62
50 - 5 - 50	33	59	104	111	83
50 - 2 - 50	33	160	188	196	194
50 - 0 - 60	25	34	32	28	44
50 - 5 - 60	12	18	29	31	15
50 - 2 - 60	29	159	98	104	131
50 - 0 - 70	50	72	19	19	22
50 - 5 - 70	37	41	58	59	39
50 - 2 - 70	37	118	66	75	75

Subgroups	First Minute Period 1	Last 2 minutes Period 1	First Minute Period 2	Second Minute Period 2	Last 2 minutes Period 2
60 - 0 - 40	4	10	74	92	86
60 - 5 - 40	6	18	89	110	91
60 - 2 - 40	13	67	135	171	246
60 - 0 - 50	8	14	27	42	58
60 - 5 - 50	6	16	59	78	51
60 - 2 - 50	23	43	59	83	138
60 - 0 - 60	4	10	34	34	30
60 - 5 - 60	22	32	92	69	52
60 - 2 - 60	2	31	39	55	68
60 - 0 - 70	11	18	18	23	16
60 - 5 - 70	10	18	40	39	17
60 - 2 - 70	19	79	51	80	90
70 - 0 - 40	5	8	33	59	80
70 - 5 - 40	5	7	82	85	86
70 - 2 - 40	4	28	84	116	161
70 - 0 - 50	6	11	42	62	73
70 - 5 - 50	9	17	92	96	74
70 - 2 - 50	4	47	83	112	148
70 - 0 - 60	5	6	28	30	29
70 - 5 - 60	28	18	82	79	49
70 - 2 - 60	1	14	42	40	75
70 - 0 - 70	14	10	25	18	20
70 - 5 - 70	1	4	10	8	11
70 - 2 - 70	7	53	55	69	82